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Towards large eddy simulation of combustion in spark ignition engines using OpenFOAM-2.3.x

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Motivation
• Internal combustion engine simulations are commonly performed using RANS approach, it gives correct estimate of global quantities but by nature not adapted to describe phenomena strongly linked to cyclic variation.
• Large eddy simulation is a promising technique to determine the cyclic variability.

Objective
• To develop a code in OpenFoam for LES of combustion in spark ignition engines.
• This includes implementation of
  • efficient chemistry solver
  • combustion model adapted for LES
  • ignition model

Implementation of Chemistry Solver
• SpeedChem\(^1\) was coupled with OpenFOAM-2.3.x
• Simulation time improved by approximately 4-7 times compared to standard chemistry solver in OpenFOAM

Combustion Model
• The characteristic time scale combustion model of Abraham et al\(^2\) was implemented in OpenFOAM

\[
\frac{Y_i}{\tau_l} = \frac{1}{c} \left( Y_i - Y_{eq,i} \right)
\]

\(\tau_l\) = laminar time scale, time to reach equilibrium
\(\eta\) = laminar time scale, time to reach equilibrium

\(\tau_l = C_2 \frac{k}{\varepsilon} \)

\(k\) = turbulent kinetic energy
\(\varepsilon\) = dissipation of turbulent kinetic energy
\(C_2\) = constant depending on turbulence model

\[f = \frac{1 - \exp(-r)}{0.432}\]

\[r = \frac{\sum_{product}}{\sum_{reactive\ species}}\]

Validation
• Implementation of chemistry solver and combustion model was checked by comparing flame speeds with experimental values\(^3\)\(^4\)

Set up
• Fuel: iso-octane/methane
• Mechanism: ERC PRF83/GRI 3.0
• Constant volume: 0.15*0.15*0.15 m\(^3\)
• No. of cells: 313480
• Spark location: center of domain
• \(T_u\), \(p_u\), \(\Phi\): 360 K /1 atm./1

Current Results:
• The laminar flame speed and turbulent flame speeds for varying turbulence intensity match well with experimental results.

Future Works:
• Use LES turbulence model and compare the results.
• Implement an ignition model
• Use for engine simulation

Reference